The return to education and its conjunction with technology in economic growth in Japan

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Abstract

This study estimates the aggregate return to schooling using panel data of Japan's prefectures, controlling for technological context. The results of single-stage OLS and Fixed Effects estimations of a standard aggregate production function, without the control for technology, indicate that the return to schooling is positive. The model then interacts the schooling variable with GDP shares of the secondary and tertiary industries, finding that schooling exhibits robust complementarity with secondary industry, especially with the manufacturing sector. The study further controls for the endogeneity of the schooling decision, in which the initial demand for schooling is likely to be elevated by the presence of a relatively extensive supply of manufacturing jobs. The estimation strategy employs a two-stage procedure. The results indicate that when interacted with sectoral distributions, the contribution of schooling is positive and significant. The study thus demonstrates the importance of controlling for the role of technological context in determining the effectiveness of schooling in regional economic growth.

Key words: Return to education; Economic growth; Aid efficiency

1. Introduction

Backed by a large body of empirical literature that shows a positive association between educational attainment and productivity, the academic and policy communities widely agree that education is essential for economic growth. Often referenced in support of this proposition is Japan's rapid economic growth since the 1950's in conjunction with the high educational attainment of Japan's population. While seemingly plausible, the proposition that the private and social returns to education are high, some considerations cast doubt on the nature of the link between education and economic growth. Specifically, substantive endogeneity issues rise concerning the role of technology as an omitted variable. That is, there may be reasons to anticipate that the returns to educational investment are systematically affected by the extent and nature of technological opportunity available in the workplace for applying the accumulation of human capital.

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This study empirically tests the return to education, taking the role of technology into account, in the context of Japanese economy. Specifically, the analysis allows for the fact that a certain skill obtained through education is effective for productivity improvement only when it is connected to a certain technology available in the economy. If an increase in educational attainment is motivated by a higher demand resulting from workers' being motivated to migrate from low-skill industry to high-skill industry, the technological advancement associated with Japan's industrial development may have been the necessary condition for Japanese workers, and thus the Japanese economy as a whole, to benefit from educational investment. In fact, during the period of rapid growth, enrollment and attainment of upper secondary and higher education steadily increased, along with Japan's industrial structural shift away from its traditional agricultural economy. Lacking the perspective of the role of technological context could overvalue the importance of educational investment. The implication of this research finding is significant especially for Japanese policy making concerning the international aid to technologically stagnant developing countries.

This study first estimates the return to average educational attainment based on Japanese regional data from 1960 to 2000, by estimating a regional production function that incorporates Mincer's (1974) wage function as a measure of human capital. The results indicate a positive aggregate return to education, which is in line with the implication of the micro-based estimates of private return to education in the literature. Next, the model interacts the educational attainment variable with each industry's GDP share in the aggregate production function, to test if the positive return to education is conditional on technological advancement due to Japan's industrial sectoral shift. The results indicate that the complementarities of education strongly exist with secondary industry, and weakly exist with tertiary service sector. The analysis then utilizes the mechanism of the demand for education in order to address endogeneity bias due to causal relationship between technology and education. With the instrumental variable for schooling, this study controls for endogeneity, using the two-stage procedure to estimate returns to schooling as they interact with Japan's varied end evolving industrial structure across prefectures.

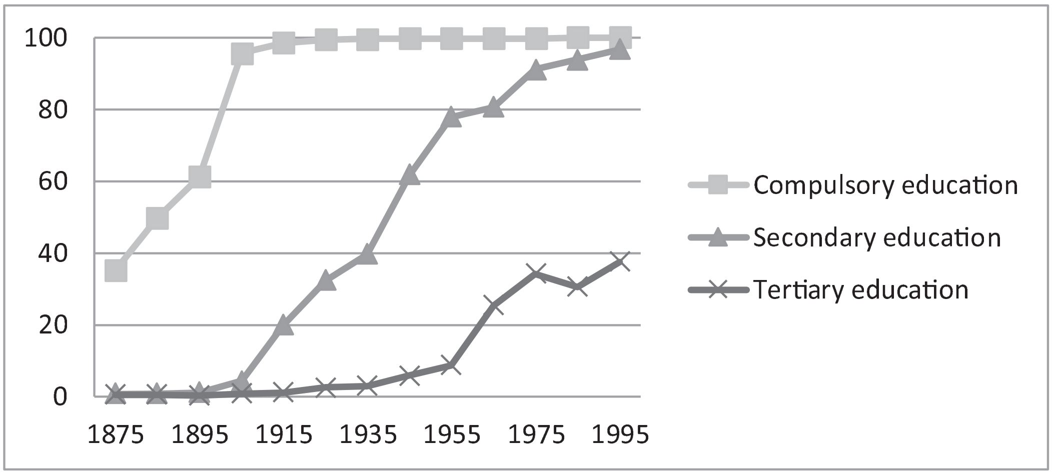
While these results provide additional support for the importance of education in the process of economic growth, they demonstrate that the positive effect of education on aggregate productivity is conditional on the presence of industry skill complementarities with education. This is consistent with the observation of structural shift towards a dominant manufacturing sector during rapid economic growth in Japan. In addition, this implies the need for careful consideration when the Japanese government allocates its ODA budget for educational purposes to technologically stagnant poor countries.

2. Background

2.1. Education in Japan

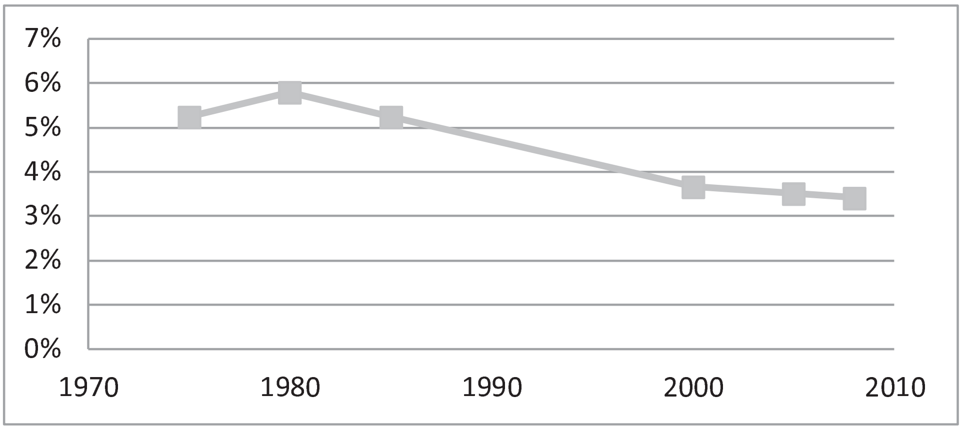
As shown in Figure 1, the enrollment rate for compulsory education, consisting of 6 years of elementary school and 3 years of lower-secondary school (junior high school), surged around the late 19th century, and universal primary education was achieved by the beginning of 20th century. Currently, most of the students who have completed the compulsory level proceed to the next 3 years of upper-secondary school (high school) education, and the demand for further education at the university level is growing steadily. On the other hand, public spending on education as a percentage of GDP is decreasing as shown in Figure 2. This may result from Japan's declining birth rate (decreasing number of children), which resulted in mild growth of average adult educational attainment in the last decade. According to OECD (2010), the annual average growth rate of the number of working-age population who attained tertiary education between 1997 and 2008 is 3.1% in Japan, compared to OECD average of 4.6%. Nevertheless, Japan possesses a large share of highly-educated workforce in the world, having 14.7% of tertiary-educated individuals living in the entire OECD countries, following the US which has the highest share of 33.5%. This observation is often presented in connection with Japan's rapid post-war economic growth, implying the contribution of high human capital stock to economic growth.

Figure 1. Transition of school enrollment rates in Japan (%)



Source: White Paper on Education

Figure 2. Public spending on education as % of GDP in Japan

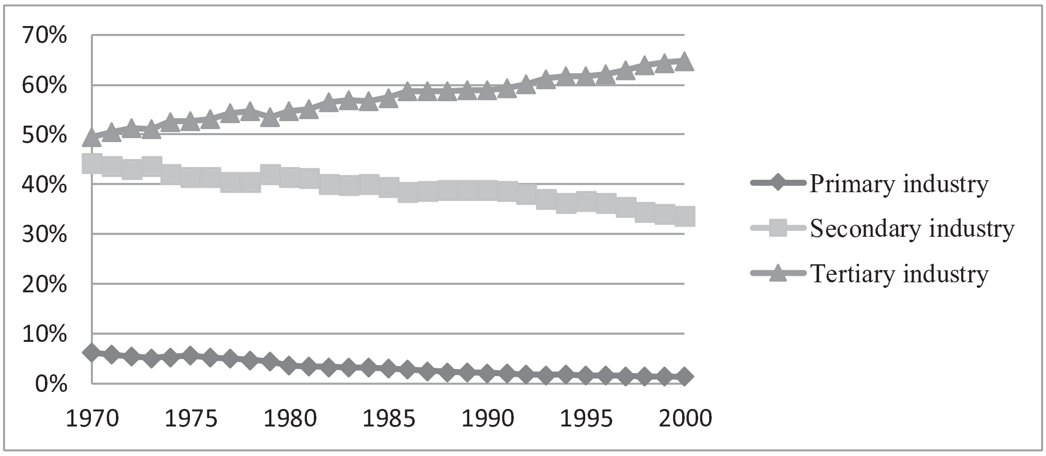


Source: World Development Indicator

2.2. Industrial composition and its shift in Japan

Japanese economy experienced rapid growth starting around the mid-1950s, until it slowed in the 1970s due to the oil shock. After a moderate growth and a bubble boom in the 1980s, Japan entered a long recession in 1990’s. During these periods, Japan's regional disparity in per-capita income became smaller. Barro and Sala-i-Martin (1992) estimate the convergence growth model using the prefectural data of Japan from 1955-90, which indicates that the Japanese regional per-capita GDP converged at the rate of 1.9% per annum.

Figure 3. Trend of industry shares of GDP in Japan

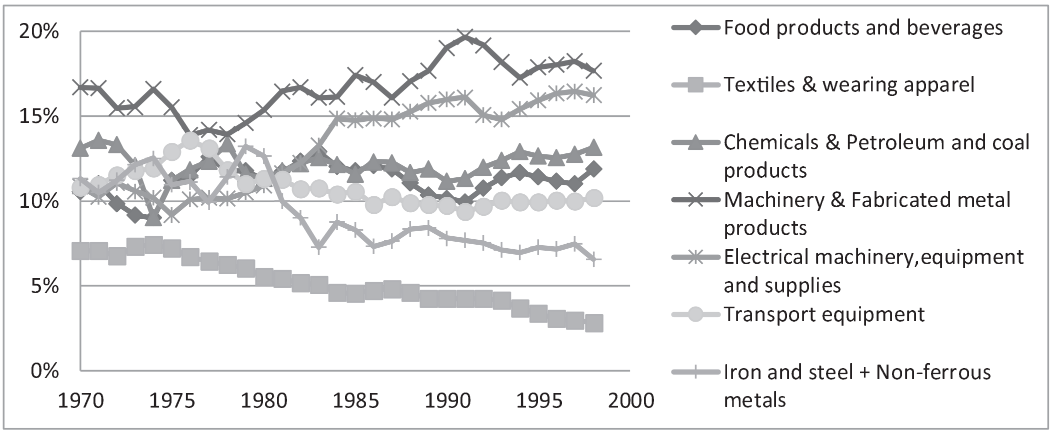


Source: National Economic Statistical Yearbook

Figure 3 shows the development of the shares of each of the primary, secondary and tertiary industries in GDP from 1970 to 2000. The share of primary industry, mainly agriculture, was already low in 1970 accounting for 6.2%, and it even declined reaching to 1.4% in 2000. The tertiary industry share increased steadily up to more than 60% in 2000, in which service activities and real estate sectors contributed to its growth. On the other hand, secondary industry does not grow in size, accounting for around 35-40% of the total GDP.

Figure 4 shows the transition of industrial composition within secondary industry, where the highest share is machinery and fabricated metal products, followed by electrical machinery and equipment that increased from 11% in 1970 to 17% in 2000. Instead, iron and metal products, as well as textile and apparel, declined during this period. According to Fujita and Tabuchi (1996), this period corresponds to the phase of a transition of Japanese economy from material-based heavy industries to advanced machine industries, and to high-technology and knowledge-intensive industries. This shift in industrial composition towards high-tech industries is considered due to high oil price after the oil shocks in 1970's, and yen-appreciation after the introduction of floating exchange rate system in 1973 as well as Plaza Accord in 1985. Although the total size of secondary industry seems stable, various restructuring occurred within the industry, in which new technology was continuously introduced.

Figure 4. Manufacturing sector components shares in GDP



Source: National Economic Statistical Yearbook

Kariya (2009) observes a rapid growth of upper-secondary school enrollment rate during 1960s and 1970s associated with the decline of agricultural industry. He explains that the acquisition of skills by going to school was vital in order for farmers to migrate from primary industry to secondary industry and tertiary industry. The increase in schooling demand was driven by a higher return to acquiring skills and knowledge, caused by a technological advancement due to industrial restructuring in Japanese economy described above.

3. Literature Review

3.1 Estimates of Mincer's wage function

The Mincer's wage function has been estimated all over the world. According to the survey conducted by Psacharopoulos and Patrinos (2004), numerous researches constantly find positive return to education, and the average rate of return to each one year of schooling is about 10%. A clear pattern is found; as the income level of the country decreases, the average years of schooling decreases and the return to education increases. Intuitively, this pattern corresponds to diminishing return to human capital.

As for Japan, Yasui and Sano (2009) review the literature estimating the wage function using data between 1970's and 1990's. Estimates of the rate of return to an additional year of schooling range from 7% to 12%. They also estimate the return as 9% using 2004 data, rising to 13% when parents' schooling is used as an instrument. Oshio (2002) uses census data in 2000 to estimate the return to schooling, and estimates the rate to be about 7% for male and 9% for female workers. According to the literature review by Oshio and Seno (2005), the return to education has been stable during the 1980's and afterwards.

Positive private return to education should be reconciled with positive *macroeconomic*, or aggregate, return to education: regional average income growth associated with growth of regional average educational attainment. This motivates the investigation of the aggregate impact of average educational attainment of regional population.

3.2 Aggregate return to education

There are studies that evaluate the effect of education on prefectural economic growth in Japan. These studies use average educational attainment of the prefectural population based on census data. Nakazato (1999), who evaluates the contribution of public physical capital investment on regional economic growth, uses a convergence growth model which includes human capital variables at the initial year as a control variable. The human capital is proxied by the shares of population over age of 15 who completed secondary and tertiary education. The estimated coefficient of human capital is negatively significant at 5% level for the period from 1970 to 1980, and insignificant for the other ten-year periods. The author mentions a possibility that the educational variables used in the estimations are not appropriate as a proxy for human capital stock. Shioji (2001) employs convergence growth model to investigate the effect of regional net migration on the composition of human capital variables (educational attainment and age), and its effect on economic growth. The model includes the initial-year level of human capital, as well as its growth rate from 1960 to 1990. The estimated coefficients of human capital variables are not significant in any of the periods. Although this study finds that more educated workers tend to migrate and changes regional human capital structure, a positive effect of human capital is not detected. Thus, these studies using Japanese prefectural data show no association between initial average educational attainment and subsequent prefectural economic growth. Konishi (2003) estimates the log-differenced Cobb-Douglas aggregate production function similar to Benhabib and Spiegel (1994). The data covers 36 regions from 1980 to 1995, based on census data. Least absolute deviations (LAD) method is employed to minimize the effect of outliers of educational data, as well as OLS. The results indicate a positive and significant influence of the growth of average years of schooling on output growth, both in LAD and OLS estimates. These studies thus show a possibility that an accurately estimated educational attainment data is actually a good proxy of human capital.

Overall, prefectural variation in average schooling years has often failed to explain the variation in aggregate productivity in the literature. So the conventional approach emphasizing the effect of the average educational attainment tends not to provide the evidence consistent with micro findings.

4. Model Specification

The model to be estimated in this study employs aggregate production function augmented by human capital. The aggregate human capital in the model is constructed as the aggregation of the human capital of all individuals within each region, thereby widely recognized contribution of education to individual worker's productivity is linked to its aggregate productivity. The idea of aggregating individual human capitals is similar to macro-Mincer wage function of a representative worker by Heckman and Klenow (1997) and Hall and Jones (1999).

The basic model to be estimated is

$$\ln(y_{it}) = \mu_{it} + \alpha \cdot \ln k_{it} + \beta \cdot \ln(S_{it}), \qquad (1)$$

where y_{it} and k_{it} are GDP per worker and physical capital per worker, and $\overline{S}_{it}$ is the average years of schooling in the prefecture i in the year t. This assumes that the return to education is constant across regions, regardless of technological context. The coefficient of $\ln(\overline{S}_{it})$ reflects Mincer's private return to education that has been estimated in the past studies.

The years of schooling variable are then interacted with shares of each industry in GDP, where interaction terms of all the industries other than primary industry are included in the basic equation (1);

$$\ln(y_{it}) = \mu_{it} + \alpha \cdot \ln k_{it} + \beta \cdot \ln(\overline{S}_{it}) + \gamma \cdot (\ln(\overline{S}_{it}) \cdot P_{2,it}) + \theta \cdot (\ln(\overline{S}it) \cdot P_{3,it}) \qquad (2)$$

where $P_{2,it}$ and $P_{3,it}$ are GDP share of each of secondary and tertiary industries, respectively. γ and θ reflect differences in the rates of return to education between each of these industries in relation to primary industry.

Equations (1) and (2) are estimated with OLS and Fixed Effects estimation methods to identify the return to educational attainment in Japan, and its variation across industries.

To address the endogeneity bias due to reverse causality between GDP growth and educational growth, a demand equation for education is introduced, which is assumed to take a form:

$$\overline{S}_{it} = c_{it} + d \cdot P_{2,it-10} + e \cdot P_{3,it-10}.$$

This means, current average educational attainment is determined by 10-year lagged GDP shares of secondary and tertiary industries. The underlying assumption is that the educational attainment of workers in the current work force population is affected by a schooling decision of each of the workers in the past, and technological level in the past is expected to proxy the incentive for those workers to be enrolled in school. This demand equation is used as the first-stage regression in two-stage least square (2SLS) estimation of the equation (1) and (2).

5. Data description

Regional aggregate data of 47 prefectures in Japan are collected to analyze the effect of differences in the educational attainment of regional population on economic growth. Among these prefectures, 13 prefectures are classified into 3 areas, namely, Kanto area (Tokyo, Saitama, Chiba, Kanagawa), Kansai area (Osaka, Kyoto, Hyogo, Nara, Shiga, Wakayama), and Chubu area (Aichi, Gifu, Mie). These areas are the three major urban areas, and their well-developed transport systems enable many of the workers to commute across boundaries within each area. Hence this grouping of the prefectures avoids the mismatch between the regional economic indicators and the characteristics of the population due to this commuting effect.

Therefore, the following analysis is conducted based on these 3 consolidated areas and the other 33 prefectures (excluding Okinawa due to lack of data in the early periods); 36 areas in total. Data for annual real GDP, the number of employees, fixed capital formulation, and the breakdown of GDP by industry in each prefecture are acquired from the Prefectural Economic Statistical Yearbook. The analysis uses a panel of 36 regions during the time period from 1960 to 2000 with a 10-year interval. Table 1 and Table 2 summarize the data.

The total fixed capital stock of each of 46 prefectures is calculated using the perpetual inventory method. In this method, the capital stock at the year 2000 as the benchmark is computed first, and the stocks of the other years are calculated from the benchmark back to 1960, using investment data and depreciation rate assumption.[2] The stock values are the addition of private fixed capital and public fixed capital.

Prefectural population with each type of the last completed educational level (upper-secondary school, 2-year junior college or specialized training college, and University) is used to estimate the average years of

2 The calculation method is explained in Appendix.

education of the population in each prefecture. The data are based on the National Census, and are available for every ten years from 1960 to 2000. The population share of graduates of each level of education is computed by dividing the number of graduates of each educational level by the total population of the age 15 and over. This is multiplied by the standard years of completion for each level, and then added up to construct the series of prefectural average years of schooling. It is assumed that every worker has completed 9 years of compulsory education, which consist of primary school and lower secondary school. Therefore, the average years of education in each prefecture is defined as that of the post-compulsory education (upper secondary school is denoted as secondary school hereafter). One of the shortcomings of the data above is that years of education in graduate school, such as the attainment of master and PhD degrees, cannot be included because the data are not available.

Another weakness is that the data are available only for prefectural working-age population, not workforce or employees. Both of these conditions may lead to underestimation of the average education of the prefectural workforce. The definition of years of education implicitly assumes that workers start their post-compulsory education right after the end of compulsory education, complete it continuously without repetition, and never return to school again.[3] The definition also assumes that the human capital stock does not depreciate over time. After an individual worker acquires skills by receiving education, his productivity keeps its level until he leaves working-age group.

Table 1. Summary statistics: Japan

1960-2000	Obs.	Mean	Std Dev.	Max	Min
Regional GDP per worker (million JPY, 2000 price)	180	3.68	1.85	7.47	0.70
Private capital per worker (million JPY, 2000 price)	180	9.87	7.77	25.89	0.08
Public capital per worker (million JPY, 2000 price)	180	2.73	2.33	9.85	0.11
Average years of post-compulsory education	180	1.66	0.66	3.15	0.60
Average years of secondary education	180	1.33	0.46	2.11	0.52
Average years of tertiary education	180	0.33	0.20	1.04	0.07
Secondary industry share in GDP	180	36.1%	8.5%	55.0%	15.5%
Tertiary industry share in GDP	180	52.6%	8.2%	72.6%	33.4%

3 It is assumed that junior college graduates do not continue their study at university.

Table 2. Summary statistics by year: Japan

Variables		1960	1970	1980	1990	2000
Regional GDP per worker (million JPY, 2000 price)	Mean	1.065	2.459	3.792	5.213	5.860
	STD	0.256	0.473	0.561	0.815	0.692
Private capital per worker (million JPY, 2000 price)	Mean	0.343	3.541	9.240	14.764	21.467
	STD	0.143	0.794	1.485	1.933	2.442
Public capital per worker (million JPY, 2000 price)	Mean	0.206	0.896	2.477	3.894	6.180
	STD	0.069	0.248	0.575	0.997	1.653
Ave. years of post-compulsory education	Mean	0.80	1.16	1.70	2.12	2.51
	STD	0.18	0.23	0.24	0.23	0.22
Female	Mean	0.70	1.04	1.55	1.95	2.34
	STD	0.17	0.21	0.23	0.22	0.22
Ave. years of secondary education	Mean	0.70	0.98	1.39	1.67	1.91
	STD	0.14	0.17	0.17	0.14	0.11
Ave. years of tertiary education	Mean	0.10	0.17	0.31	0.45	0.60
	STD	0.04	0.06	0.09	0.10	0.12
Primary industry share in GDP	Mean	26.0%	14.0%	8.0%	5.1%	3.1%
	STD	9.2%	6.2%	3.7%	2.8%	1.6%
Secondary industry share in GDP	Mean	29.4%	37.4%	38.7%	39.4%	35.8%
	STD	8.4%	8.2%	7.5%	7.8%	6.8%
Manufacturing	Mean	22.2%	26.7%	26.8%	27.8%	25.4%
	STD	8.7%	8.9%	8.8%	8.3%	7.7%
Construction	Mean	7.2%	10.7%	11.9%	11.5%	10.3%
	STD	1.7%	2.2%	2.3%	1.7%	2.2%
Mining industry	Mean	2.8%	1.4%	0.7%	0.4%	0.3%
	STD	2.7%	1.4%	0.5%	0.2%	0.2%
Tertiary industry share in GDP	Mean	44.6%	48.6%	53.3%	55.5%	61.1%
	STD	5.2%	5.2%	5.9%	6.5%	6.4%

6. Estimation results and discussion

Table 3. OLS and FE estimation of the return to education

Dependent variable: Log of real GDP per worker

Specification	J1	J2	J3	J4
Estimation method	OLS	OLS	FE	FE
ln (fixed capital per worker)	0.262***	0.233***	0.175***	0.156***
	(0.031)	(0.029)	(0.027)	(0.028)
ln (Ave. years of schooling)	0.649***		0.483***	
	(0.053)		(0.096)	
ln (Ave. years of secondary education)		0.075		0.249***
		(0.086)		(0.097)
ln (Ave. years of tertiary education)		0.412***		0.300***
		(0.049)		(0.092)
Dummy 1960	0.135	0.077	-0.423***	-0.269*
	(0.116)	(0.106)	(0.133)	(0.145)

Dummy 1970	0.110**	0.116**	-0.179**	-0.046
	(0.055)	(0.050)	(0.077)	(0.094)
Dummy 1980	0.039	0.056*	-0.100***	-0.027
	(0.032)	(0.029)	(0.040)	(0.050)
Dummy 1990	0.088***	0.098***	0.027	0.060**
	(0.024)	(0.022)	(0.021)	(0.026)
Constant	0.365***	1.218***	0.782***	1.280***
	(0.084)	(0.119)	(0.100)	(0.134)
Adjusted R2	0.981	0.984	0.993	0.994
# of observations	180	180	180	180

Note: ***: significant at 1%, **: significant at 5%, *: significant at 10%.

Table 3 shows the OLS and Fixed Effects (FE) estimation results of the models based on the equation (1). The employed dataset for the estimations consists of the prefectural aggregate data from 1960 to 2000 with 10-year interval (180 observations). The coefficients of the average years of schooling variable in the specification J1 (OLS) and J3 (FE) are both positive and significant at the 1 percent level. The effect of education by each educational level is examined by the specification J2 and J4, where schooling is split into secondary and tertiary education. According to the estimates, the return to tertiary education is positive and significant in both OLS and FE estimates, and the return to secondary education is positive and significant in FE estimate.

The growth of average educational attainment is positively associated with the growth of regional productivity in Japan during the observed period. Since the human capital stock in the model is the aggregation of the individual human capital within each region, the detected positive aggregate return to education affirms the notion that the typical micro findings of a positive private return to education actually imply a positive effect of a growth of regional average education on aggregate productivity improvement in the region. Among the educational levels, tertiary education, consisting of university education and junior college education, show positive return with statistical significance. The secondary schooling is positive and significant in more reliable estimation, indicating both of the educational levels effective in enhancing the regional productivity.

Table 4. Interacting years of schooling and industrial shares

Dependent variable: Log of real GDP per worker

Specification	J5	J6	J7	J8	J9	J10	J11	J12
Estimation method	OLS	OLS	OLS	OLS	FE	FE	FE	FE
ln (fixed capital per worker)	0.250***	0.244***	0.163***	0.102***	0.164***	0.161***	0.135***	0.086***
	(0.030)	(0.031)	(0.031)	(0.033)	(0.027)	(0.028)	(0.030)	(0.033)
ln (Ave. years of schooling)	0.064	0.223	-0.661***	-0.726**	0.509***	0.612**	0.071	-0.223
	(0.230)	(0.348)	(0.241)	(0.336)	(0.164)	(0.266)	(0.238)	(0.336)
ln (years of schooling)	0.860***		1.266***		0.134		0.542**	
x Secondary industry share	(0.249)		(0.256)		(0.203)		(0.264)	
ln (years of schooling)		0.767**		1.294***		0.048		0.816**
x Manufacturing share		(0.335)		(0.324)		(0.266)		(0.347)
ln (years of schooling)		0.587		0.710		0.037		0.228
x Construction share		(0.858)		(0.827)		(0.671)		(0.658)
ln (years of schooling)		1.024		3.440*		0.686		2.754
x Mining share		(1.750)		(2.042)		(1.397)		(2.056)
ln (years of schooling)	0.498*	0.400	1.136***	1.129***	-0.415	0.523	0.055	0.509
x Tertiary industry share	(0.271)	(0.362)	(0.283)	(0.365)	(0.282)	(0.359)	(0.335)	(0.437)
Secondary industry share			1.175***				0.567**	
			(0.195)				(0.241)	
Manufacturing share				1.635***				1.210***
				(0.226)				(0.301)
Construction share				1.052**				0.618
				(0.532)				(0.536)
Mining share				2.768***				2.111***
				(0.686)				(0.716)
Tertiary industry share			1.110***	1.597***			0.557**	1.136***
			(0.226)	(0.272)			(0.253)	(0.311)
Dummy 1960	0.075	-0.009	-0.292**	-0.626***	-0.665***	-0.681***	-0.694***	-0.806***
	(0.114)	(0.121)	(0.122)	(0.134)	(0.174)	(0.186)	(0.193)	(0.192)
Dummy 1970	0.110*	0.041	-0.072	-0.247***	-0.348***	-0.358***	-0.340***	-0.364***
	(0.057)	(0.066)	(0.061)	(0.069)	(0.117)	(0.124)	(0.128)	(0.126)
Dummy 1980	0.044	0.017	-0.034	-0.109***	-0.199***	-0.205***	-0.187***	-0.178***
	(0.035)	(0.037)	(0.035)	(0.037)	(0.065)	(0.070)	(0.070)	(0.070)
Dummy 1990	0.085***	0.080***	0.054**	0.028	-0.029	-0.032	-0.022	-0.008
	(0.025)	(0.025)	(0.024)	(0.023)	(0.034)	(0.037)	(0.037)	(0.037)
Constant	0.375***	0.457***	-0.284*	-0.407**	0.981***	0.995***	0.530**	0.125
	(0.084)	(0.093)	(0.150)	(0.198)	(0.142)	(0.151)	(0.249)	(0.296)
Adjusted R2	0.982	0.982	0.985	0.987	0.994	0.994	0.994	0.995
# of observations	180	180	180	180	180	180	180	180

Note: ***: significant at 1%, **: significant at 5%, *: significant at 10%.

Table 4 shows the estimation results of the models based on the equation (2) in which schooling variable is interacted with GDP shares of secondary and tertiary industries. The years-of-schooling variable is in logarithmic form. The specification J5-J8 and J9-J12 employ OLS and FE estimation methods, respectively.

According to the estimation results of J5 (OLS) and J9 (FE), the coefficient of the interaction between schooling and secondary industry share in J5 is positive and significant at the 1 percent level, although that turns to insignificant when fixed effects are controlled in J9. The interacting term of tertiary industry with education is only slightly significant in J5. The years-of-schooling variable that stays independently as a reference (showing the return to education when secondary and tertiary industry shares are zero) is significantly positive in J9, but insignificant in J5.

The specification J6 (OLS) and J10 (FE) split the secondary industry into manufacturing, construction, and mining sectors. The results are similar to those in J5 and J9. The result of J6 seems to show that the complementarity of secondary industry with education in J5 is led by manufacturing sector rather than construction and mining sectors. The model J7 (OLS) and J11 (FE) add industrial share variables independently in the model J5 and J9. The interaction between schooling and secondary industry share is now positive and significant at the 5 percent level in both J7 and J11. These results give robustness to the positive complementarity between education and secondary industry found in J5. The interaction between schooling and tertiary industry share is significant in J7 at 5 percent level, but it remains insignificant in J11. The coefficient of the separate years-of-schooling variable is negatively significant in J7, but it also remains insignificant in J11. The results of J8 (OLS) and J12 (FE) split the secondary industry into three sectors, and their results are again similar to those in J7 and J11, confirming the positive complementarity of education with manufacturing sector in secondary industry.

In total, a positive complementarity between education and secondary industry, especially manufacturing sector, is constantly detected; aggregate return to education in a region which has higher secondary industry share in GDP is significantly higher than the other regions. The skills and knowledge obtained through formal education have enhanced worker's productivity in secondary industry in Japan during the observation period. This result appears intuitive in Japan where manufacturing sector experienced a technological shift from low-tech to high-tech production over the decades after 1960. On the other hand, the complementarity of education seems weak or not present with tertiary industry, implying that the formal education did not increase aggregate productivity in service sector as a whole. A positive complementarity between education and primary industry, mainly agriculture, is not observed, either. This result also seems intuitive by considering the agricultural sector in Japan which has not experienced major technological advancement.

The industrial composition, representing technological context, plays a role in determining the effect of education, according to these results. However, they might be affected by estimation bias due to endogeneity between education and technology. The following estimations address this issue by using 2SLS estimation method.

Table 5. First stage regression of 2SLS estimation (demand for schooling)

Dependent variable: Log of average educational attainment

Specification	J13	J14
Estimation method	OLS	FE
10-year lagged secondary industry share in GDP (%)	1.708***	0.924***
	(0.119)	(0.100)
10-year lagged tertiary industry share in GDP (%)	1.692***	0.543***
	(0.166)	(0.128)
Dummy 1970	-0.433***	-0.636***
	(0.034)	(0.023)
Dummy 1980	-0.242***	-0.337***
	(0.024)	(0.013)
Dummy 1990	-0.123***	-0.154***
	(0.021)	(0.009)
Constant	-0.695***	0.251***
	(0.129)	(0.100)
Adjusted R2	0.930	0.991
F-statistic for joint significance of industry share variables	103.15	44.08
p-value	0.00	0.00
# of observations	144	144

Note: ***: significant at 1%, **: significant at 5%, *: significant at 10%.

Table 5 shows the first-stage estimation results of the 2SLS, in which current average educational attainment is regressed on 10-years lagged secondary and tertiary industry shares in GDP. Educational attainment of the current workforce population is affected by their past schooling choice, and a higher technological level in the regional economy may create an incentive for schooling. Therefore this regression is estimating the impact of secondary and tertiary industry shares, which represent technological level, on current educational attainment, through demand for schooling. The results of both J13 and J14 indicate that the secondary and tertiary industry shares 10 years ago are the significant determinant of the current educational capital. F-statistic for joint significance of the lagged share variables indicates sufficient strength of these variables as instruments for the schooling variable.

Table 6. Second stage regression of 2SLS estimation (return to schooling)

Dependent variable: Log of real GDP per worker

Specification	J15	J16
Estimation method	2SLS	FE2SLS
ln (fixed capital per worker)	0.467***	0.281***
	(0.061)	(0.084)
ln (average years of schooling)	0.621***	0.672***
	(0.096)	(0.185)
Dummy 1970	0.461***	0.163
	(0.074)	(0.137)
Dummy 1980	0.202***	0.064
	(0.038)	(0.067)
Dummy 1990	0.160***	0.099***
	(0.023)	(0.031)
Constant	-0.238*	0.284
	(0.133)	(0.209)
Adjusted R2	0.959	0.986
# of observations	144	144

Note: ***: significant at 1%, **: significant at 5%, *: significant at 10%.
log(average years of schooling) is instrumented by 10-year lagged secondary industry share and 10-year lagged tertiary industry share in the first stage regression.
Estimation methods:

J15. First stage with OLS, Second stage with OLS

J16. First stage with FE, second stage with FE

Table 6 shows the second-stage regression results of the equation (1), in which schooling variable is instrumented by lagged secondary and tertiary industrial share variables. In terms of return to education, the estimates of both J15 (OLS) and J16 (FE) are positive and significant, and their size are close to the coefficients in J1 and J3 in Table 3. The fact that the return to education estimated with 2SLS is very close to the return estimated with OLS and FE assures the findings and implication from J1 and J3 in Table 3, indicating positive effect of education on aggregate productivity. In other words, such positive effect of education on Japanese regional economy is reflecting the incentive mechanism in which technology creates demand for schooling.

Table 7 shows second-stage regression results of 2SLS estimation of the models based on the equation (2), interacting schooling variable with industrial share variables. The schooling variable is instrumented by lagged secondary and tertiary industry shares. The specifications correspond to those in Table 4, where J17-J20 use OLS in both first- and second-stage regressions, and J21-J24 use FE in both stages.

Table 7. Second stage regression of 2SLS estimation (interacting schooling and industrial shares)

Dependent variable: Log of real GDP per worker

Specification	J17	J18	J19	J20	J21	J22	J23	J24
Estimation method	2SLS	2SLS	2SLS	2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS
ln (fixed capital per worker)	0.339***	0.301***	0.366***	0.286***	0.421***	0.392***	0.455***	0.412***
	(0.056)	(0.056)	(0.058)	(0.064)	(0.078)	(0.082)	(0.083)	(0.093)
ln (Ave. years of schooling)	-2.015***	-2.085***	-2.098***	-1.815***	-0.821	-1.249**	-1.412**	-1.729***
	(0.407)	(0.540)	(0.417)	(0.631)	(0.527)	(0.618)	(0.588)	(0.663)
ln (years of schooling)	2.776***		2.844***		1.617***		1.968***	
x Secondary industry share	(0.405)		(0.404)		(0.531)		(0.544)	
ln (years of schooling)		2.936***		2.573***		2.001***		2.261***
x Manufacturing share		(0.516)		(0.573)		(0.600)		(0.617)
ln (years of schooling)		1.923**		1.726		2.368***		2.323**
x Construction share		(0.917)		(1.314)		(0.891)		(1.049)
ln (years of schooling)		5.362		5.250		5.582		5.730
x Mining share		(3.671)		(4.077)		(4.769)		(5.074)
ln (years of schooling)	2.681***	2.799***	2.208***	1.957***	0.883	1.323*	1.004	1.397*
x Tertiary industry share	(0.429)	(0.538)	(0.483)	(0.683)	(0.621)	(0.696)	(0.664)	(0.760)
Secondary industry share			0.722*				0.617**	
			(0.387)				(0.265)	
Manufacturing share				1.104**				0.683
				(0.514)				(0.423)
Construction share				0.862				0.535
				(0.851)				(0.699)
Mining share				1.886				0.081
				(1.216)				(1.110)
Tertiary industry share			1.158**	1.495**			0.793**	0.793
			(0.483)	(0.630)			(0.355)	(0.503)
Dummy 1970	0.239***	0.152**	0.140	-0.023	0.128	0.102	-0.029	-0.068
	(0.073)	(0.078)	(0.100)	(0.118)	(0.151)	(0.155)	(0.267)	(0.195)
Dummy 1980	0.149***	0.103***	0.084*	0.004	0.044	0.031	-0.038	-0.054
	(0.036)	(0.038)	(0.051)	(0.060)	(0.083)	(0.085)	(0.089)	(0.101)
Dummy 1990	0.145***	0.130***	0.113***	0.083***	0.080*	0.075*	0.043	0.038
	(0.022)	(0.022)	(0.027)	(0.030)	(0.041)	(0.043)	(0.044)	(0.049)
Constant	0.157	0.288**	-0.573*	-0.618	0.198	0.256	-0.253	-0.179
	(0.129)	(0.134)	(0.328)	(0.453)	(0.211)	(0.215)	(0.299)	(0.393)
Adjusted R2	0.969	0.970	0.970	0.971	0.989	0.971	0.990	0.990
# of observations	144	144	144	144	144	144	144	144

Note: ***: significant at 1%, **: significant at 5%, *: significant at 10%.
ln(schooling) is instrumented by 10-year lagged industrial shares.
Estimation methods:
J17-J20. First stage with OLS, second stage with OLS
J21-J24. First stage with FE, second stage with FE

The main finding in these estimates is a positive and significant coefficient of the interaction between schooling and secondary industry share, which is observed in all the estimates. Their significance level increased compared to that of the single-stage OLS and FE results, strengthening the finding of positive complementarity between education and secondary industry. The positive complementarity between education and manufacturing sector, the finding from Table 4, is also observed in the 2SLS estimates, and the significance level is higher. In addition, a positive complementarity of education is found in construction sector at the 5 percent level in the FE estimates. The coefficient of interaction between schooling and tertiary industry share is significant only at the 10 percent level when FE is used in the 2SLS estimation, while the coefficient is significantly positive when OLS is used. The coefficient of the schooling variable, that is included independently, is significantly negative in most of the estimates, showing no positive complementarity of education with primary industry.

These results are basically in line with the findings in Table 4, with higher statistical significance. That is, the complementarity of education with secondary industry, especially with manufacturing sector, is detected positive in all the specifications.

7. Conclusion

During the post-WWII period, Japan's secondary industry experienced a continuous structural change and rationalization. Besides, scientific skills and knowledge, which are frequently attributed to school education, are often associated with high technology used in manufacturing sector. Hence it is expected to find that the schooling is complementary to the secondary industry. The empirical analysis conducted in this study using panel data for Japan's regional economies indeed supports this argument. On the other hand, the positive complementarity with education is not found in primary industry. The agricultural sector in Japan has long been regulated and protected by the government, and as a result this sector did not experience a major technological advancement. In addition to agriculture not being as skill intensive, this extreme degree of regulation in Japanese agriculture may explain why such complementarity is not observed. The absence of the positive complementarity might also come from the fact that many workers in the agricultural sector have a side job in the other industries. The share of farmers with a side job was already 66% in 1960, and has increased to 82% in 2000.[4] The skills they obtained in school for their employment in secondary or tertiary industries may not be utilized for their work in the primary industry.

The estimation method used in this study addresses the concerns about a potential endogeneity bias due to mutual causal relationship between education and technology. The method utilizing past technological level as a proxy of incentive for educational investment assured the positive aggregate return to education, as well as the importance of the role of technological context in evaluating the effect of education on productivity improvement.

A positive effect of an increase in regional educational level on its economic growth seems like a simple and straightforward consequence of the typical empirical findings of the private return to education based on

[4] Agricultural and forestry census, retrieved from http://www.maff.go.jp/j/tokei/census/afc/past/stats.html

individual wage data. As a result, Japanese people may tend to emphasize the importance of providing low-cost access to schooling, as well as the quality improvement of education, in their aid policy for developing countries. However, the results of this study imply that this perspective may be too simplistic. Specifically, the return to education varies across industries and sectors, depending on varying complementarities of acquired skills and knowledge with technology used in each of the industries. If the educational aid intends to help improve recipient countries' economy, the variation in technological context in those countries needs to be taken into consideration when aid policy is formulated, since the industrial structure in developing countries is significantly different from that in Japan.

Appendix: Fixed capital stock calculation

The capital stock value at the benchmark year 2000 is computed as

$$\begin{aligned} K_{jt} &= (1-\delta_t)K_{jt-1} + I_{jt} \\ &= (1-\delta_{t-1})(1-\delta_t)K_{jt-2} + I_{jt} + (1-\delta_t)I_{jt-1} \end{aligned}$$

By iterating,

$$K_{jt} = K_{j,t-T+1}\prod_{i=t-T}^{t}(1-\delta_i) + \sum_{s=0}^{T} I_{j,t-s+1}\prod_{i=t-s}^{t}(1-\delta_i).$$

Investment, I_{jt}, is defined as the real fixed capital formation for each of 46 prefectures from 1955 to 2000. Prefectural fixed capital formation data in 68SNA terms are available until 1999, and the data for 2000 is extrapolated using percentage change in real fixed capital formation in 93SNA (Real GDP in 2000 is also calculated by the same method). Since the annual investment data is available for 45 years, (by setting T=45) the first term in the last expression of the equation above is assumed to be small enough to cancel for the calculation of the benchmark stock value. Prefectural fixed capital stock is calculated backward from 2000 to 1960 as

$$K_{j,t} = \frac{K_{j,t+1} - I_{j,t+1}}{1-\delta_t}.$$

Because the depreciation rate for each prefecture is not available, it is calculated from the private fixed capital stock and investment data of the total domestic private companies, based on "Private Firms' Capital Stock Yearbook". The calculated depreciation rate of each year ranges from 4 to 6 percent, and it was used as δ_t for the estimation of the capital stock value in 2000. The depreciation rate for public fixed capital is assumed to be 6 percent in every year.

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